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Identifying Priorities in Infrastructure Investment in Portugal

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Abstract

In this paper we use a vector autoregressive approach to analyze the effects of infrastructure investment on economic performance using a newly developed data set for Portugal. Our overall goal is to identify priorities in infrastructure investments, i.e., areas of infrastructures investments with virtuous economic and budgetary effects. We find that investments in other transportation infrastructures—railroads, ports and airports—and social infrastructures—health and education infrastructures—have the largest effects with long-term multipliers of 15.00 and 8.45, respectively. Investments in road transportation—roads and freeways—and on utilities—electricity, gas, water, refineries, and telecommunications—induce much smaller effects with multipliers of 2.75 and 3.52, respectively. We also show that for other transportation and social infrastructure investments, the short-term effects are small relative to the accumulated effects and yet, in absolute terms, they exceed the long-term effects for road transportation and utilities. Finally, we show that investments in other infrastructures and in social infrastructures will pay for themselves in the form of long-term enhanced tax revenues under rather reasonable effective tax rates. Overall, we have clearly identified other transportation infrastructures and social infrastructures as the key target areas for policy intervention in this context.

Keywords

infrastructure investment, multipliers, economic performance, budgetary effects, VAR, Portugal

1. Introduction

The recent sovereign-debt crisis in Portugal and the underlying need to pursue budgetary consolidation have resulted in a prolonged recession coupled with persistently high public deficits and public debt levels (see, for example, IMF, 2016). In this context, infrastructure investments have proven to be a politically-expedient way to cut public spending. Indeed, in the last decade, public investment was the public expenditure category with the largest relative decline having reached in recent years its lowest level in decades (see, for example, CFP, 2016). This is particularly significant as infrastructure investments were the cornerstone of the development strategies in Portugal between the late 1980s and the middle 2000s.

It is, therefore, not surprising that there have been lingering concerns about how much of the decline in infrastructure investments may have contributed to the deterioration in economic performance in the country (see, for example, Barbiero & Darvas, 2014) for a general discussion of this issue. Moreover, as the country slowly comes out of recession, the need for public policies to promote economic performance and debt consolidation remain and, in this context, infrastructure investment has resurfaced as a central point in the public policy debate. From our perspective, the central issue is the role that infrastructure investments could or should play in achieving the twin goals of promoting long-term economic performance and achieving budgetary consolidation. And here critical questions remain. Is investing in infrastructures still worth it? And, if so, in which assets? What is the relative importance of short-term demand side effects versus the long-term supply side effects of these investments? What are the ramifications of these investments for the long-term prospects of budgetary consolidation?

In this paper we analyze the impact of infrastructure investment on economic performance in Portugal, and address the questions above, first at the aggregate level, and then considering four main types of infrastructure investments—road transportation infrastructures, other transportation infrastructures, social infrastructures, and utilities. In doing so we intend to bring a level of clarity to the debate on defining strategic priorities as far as infrastructures investments are concerned.

The analysis of the economic effects of infrastructure investments was brought to the limelight by the seminal work of Aschauer (1989a, 1989b). The initial work was based on a univariate and static production function approach applied at an aggregated level to the US case. The body of empirical literature that developed in its aftermath is extensive (See, for example, Munnell, 1992; Gramlich, 1994; Kamps, 2005; Romp & de Haan, 2007; Pereira & Andraz, 2013; Bom & Ligthart, 2014; for literature surveys). The empirical literatures focuses on a large variety of issues, both for the US and for other countries, both at the aggregate level and at the industry and regional levels. A variety of econometric approaches to deal with issues of simultaneity, causality, and dynamics have been adopted in the literature.

In this paper, we use a multivariate dynamic time series approach developed in Pereira (2000, 2001) (Note 1). We employ a vector autoregressive model relating output, employment, private investment, and infrastructure investment, to estimate the long-term elasticities and marginal products of output, employment, and private investment with respect to infrastructure investment through an analysis of the resulting impulse-response functions.

This econometric approach highlights the dynamic nature of the relationship between infrastructure investment and the economy. It does so at three distinct levels: first, it explicitly addresses the contemporaneous relationships in the innovations in each variable; second, it incorporates the dynamic intertemporal feedbacks among the variables; and, third, it accommodates the existence of long-run equilibrium co-integrating relationships among the variables. Built into the approach is the simultaneous endogeneity of all of the variables and the identification of a causal relationship among the variables and infrastructure investment rather than simple correlations.

In addition, it should be pointed out that although our approach is eminently empirical, it is not a-theoretical. Indeed, our analysis is grounded in a dynamic model of the economy. In this model, the economy uses a production technology based on the use of capital and labor, as well as public infrastructure, to generate output. Given market conditions and the availability of public infrastructure, private economic agents decide on the level of input demand and the supply of output. In turn, the public sector engages in infrastructure investment based on a policy rule that relates public infrastructure to the evolution of the remaining economic variables. The estimated VAR system can be seen as a dynamic reduced form system for a production function and three input demand functions—for employment and private investment as well as infrastructure investment (a policy function). This framework captures the role of public infrastructure investment as a direct input to production and as an externality in production. Infrastructures further affect output indirectly through their effect on the demand for labor and private capital.

Aside from its immediate policy implications, this paper brings important contributions in three different areas. First, from a data perspective, we use a new and comprehensive data set for infrastructure investment in Portugal covering (see Pereira, A. & Pereira, R., 2016). This data set includes information for the period between 1978 and 2012 for road transportation—national roads, municipal roads and highways; other transportation—railroads, ports, and airports; social infrastructures—education and health facilities; and utilities—water, electricity and gas, refineries, and telecommunications. Second, from a conceptual perspective, it decomposes the marginal products between the short-term demand effects on impact and the long term supply side effects and that maps the evolution of the marginal products over time to identify patterns of decreasing marginal returns.

Third, and finally, from a policy perspective, a new taxonomy of the results is introduced in terms of the economic and budgetary dilemma. Indeed, from a taxonomic perspective, we can expect infrastructure investments to conceivably fall into three categories. If the marginal products are negative or positive but low, infrastructure investments are not important for the economy and have a detrimental effect on the budget and as such can be eliminated without significant economic or budgetary concerns. If the marginal products are positive but not sufficiently large, infrastructure investments are important for the economy but still have a detrimental effect on the public budget. Eliminating these investments although useful from a budgetary perspective is hurtful in economic terms. If the marginal products are positive and sufficiently large, infrastructure investments have positive economic and budgetary effects. Eliminating these investments hurts both the economy and the public budget.

To conclude, it should be mentioned that although this paper is an application to the Portuguese case and is intended to be directly relevant from the perspective of policy making in Portugal, its interest is far from parochial. The quest for policies that promote long-term growth in a framework of fragile public budgets is widespread and the role of infrastructure investments in this quest increasingly recognized. Indeed, among the international organizations there has been, in recent years, a remarkable renewal of interest on issues relating to public investment and, in particular, to infrastructure investments (see, for example, Council of Economic Advisers, 2016; European Central Bank, 2016; European Commission, 2014a, 2014b, 2016; IMF, 2014, 2015; and World Bank, 2016, 2017).

This paper is organized as follows. Section 2 presents the data and some stylized facts. Section 3 presents the preliminary econometric results including the VAR estimates and impulse response functions. Section 4 presents the main evidence as to the impact of infrastructure investment. Section 5 provides some international comparisons. Finally, Section 6 includes a summary and concluding remarks.

2. Data Sources and Description

We use annual data for Portugal from 1978 to 2011. The economic data are obtained from the *Instituto Nacional de Estatística* (National Institute for Statistics, Portugal) and is available online at http://www.ine.pt Gross Domestic Product (GDP), and private investment are measured in millions of constant 2005 Euros, while employment is measured in thousands of employees. Summary statistics are presented in Table 1.

Table 1. Macroeconomic Variables

	1978-2011	1980-1989	1990-1999	2000-2009
GDP Growth	0.023	0.034	0.029	0.009
Employment Growth	0.002	0.002	0.008	-0.003
Private Investment (% GDP)	22.15	20.33	22.81	23.78
Infrastructure Investments (% GDP)	4.18	2.88	4.40	5.04

GDP growth averaged 2.3% for the sample period with a clear declining trend. In particular the economy stagnated in the first decade of the new millennium with an average growth rate of just 0.9%. The evolution of employment, in turn, shows an increasing pattern from the 80s to the 90s but it actually shows a significant decline in the 2000s. Interestingly enough, private investment, and for that matter infrastructure investment, as a share of GDP showed an increasing pattern having reached the highest average over the first decade of the 2000s with 23.78%.

The data for infrastructure investment, also in millions of constant 2005 Euros, are from a new and comprehensive data set developed by Pereira, A. and Pereira, R. (2016) (Note 2). In this paper, we consider total infrastructure investment, as well as four main types of infrastructure investments: road transportation infrastructure, other transportation infrastructure, social infrastructures, and utilities infrastructure. Table 2 presents some summary information.

Table 2. Infrastructure Investments

	1978-2011	1980-1989	1990-1999	2000-2009
Percent of GDP				
Infrastructure Investments	**4.18**	**2.88**	**4.40**	**5.04**
Road Transportation	1.19	0.74	1.32	1.52
Other Transportation	0.38	0.22	0.47	0.46
Social Infrastructures	0.96	0.81	1.08	1.02
Utilities	1.65	1.11	1.53	2.04
Proportion of Total Infrastructure Investment				
Infrastructure Investments	**100.00**	**100.00**	**100.00**	**100.00**
Road Transportation	28.49	25.99	30.35	30.23
Other Transportation	8.91	7.57	10.52	9.21
Social Infrastructures	23.76	28.41	24.52	20.13
Utilities	38.85	38.04	34.61	40.43

Road transportation infrastructures include national roads, municipal roads and highways, and account for 28.49% of total infrastructure investment. Road investment grew tremendously during the 1990s under European Union support programs, with the last ten years marked by a great increase in highway investment related to the expansion of public-private partnerships. Road Investment increased from 0.74% of the GDP in the 1980s to 1.52% in the 2000s.

Other transportation infrastructures include railroads, airports and ports, and account for 8.91% of total infrastructure investment between 1978 and 2011. These investments reached their greatest levels, as a percent of total infrastructure investment, in the 1990s with the modernization of the railroad network and port expansion projects while the last ten years has also brought with it substantial growth in investment in airports compared to the previous decade. This reflects an increase from 0.22% of the GDP in the 1980s to 0.46% in the last decade.

Social infrastructures include health facilities and educational buildings. Social infrastructures account for 23.76% of infrastructure investment and show a slowly declining pattern in terms of their relative importance in total infrastructure investment. As a percentage of GDP, these investments remained stable over the last two decades representing on average 1.0%.

Finally, public utilities include electric power generation, transmission and distribution, water supply and treatment, petroleum refining and telecommunications infrastructures. Together these account for 38.85% of total infrastructure investment in the sample period. In terms of their relative importance in terms of total infrastructure investment, investments in utilities reached a peak in the 1980s, driven by the expansion of the telephone network, substantial investment in the major coal-powered electricity production units and in two refineries. More recently, the expansion of mobile communications networks as well as investments in renewable energies have contributed to sustained growth in investment in utilities since 2000. Overall, we witnessed a constant increase in importance from 1.11% of the GDP in the 1980s to 2.04% in the last decade.

Overall, investment levels grew substantially over the past thirty years, averaging 2.88% of GDP in the 1980s, 4.40% in the 1990s and 5.04% over the last decade. The increase in infrastructure investment levels is particularly pronounced after 1986, the year in which Portugal joined the EU, and in the 1990s when EU transfers within the context of the First Community Support Framework (1989-1993) and the Second Community Support Framework (1994-1999), stimulated a substantial increase in investment levels. Investment efforts decelerated substantially during the last decade during the Third Community Support Framework, 2000-2006, and the QREN (National Strategic Framework), 2007-2011. These landmark dates for joining the EU as well as the start of the different community support frameworks are all considered as potential candidates for structural breaks in every step of the empirical analysis that follows.

3. Preliminary Data Analysis

3.1 The Basic Model Set-up

Our ultimate goal is to estimate the effects of infrastructure investments on economic performance. With this objective in mind we estimate five VAR models relating output, employment, private investment, and infrastructure investments, one at the aggregate level and the other four for each of the four types of infrastructures: road infrastructure, other transportation infrastructure, social infrastructures, and utilities. This requires some preliminary steps namely a unit root and cointegration analysis of the different series as well as the determination of the VAR specifications. In turn, the VAR estimates are used to generate impulse-response functions, which requires dealing with the issue of contemporaneous correlations and how to exactly measure the effects. In this section, we present in an abridged version these different steps.

3.2 Unit Roots and Cointegration Tests (Note 3)

We start by using the Augmented Dickey-Fuller (ADF) t-tests to test the null hypothesis of a unit root in the different variables. Following Ivanov and Kilian (2005) we use the Bayesian Information Criterion (BIC) to determine the number of lagged differences, the deterministic components, as well as the dummies for the potential structural breaks to be included.

For the variables in log-levels, the t-statistics are lower, in absolute levels, than the 5% critical values. Therefore, the tests cannot reject the null hypothesis of a unit root. In turn, for the tests applied to the first differences of the log-levels, i.e., the growth rates of the original variables, all critical values are greater, in absolute value, than the 5% critical value. Therefore, we can reject the null hypotheses of unit roots in the growth rates. We take this evidence as an indication that stationarity in first differences is a good approximation for all the time series under consideration.

We now test for cointegration among output, employment, private investment, and infrastructure investment, as well as for each one of the four infrastructure investment variables. We use the standard Engle-Granger approach to test for cointegration (Note 4). In each case, and following the standard approach, we perform four tests, with each case having a different endogenous variable. In all of the tests, again following Ivanov and Kilian (2005), the optimal lag structure is chosen using the BIC, and deterministic components and structural breaks are included if found to be statistically significant.

The value of the t-statistics is lower, in absolute value, than the 5% critical values in all but five of the forty cases considered, and never in more than one of the four cases considered for each infrastructure type. Moreover, all the test statistics without exception are lower, in absolute value, than the 1% critical values. Thus, our tests cannot reject the null hypothesis of no cointegration.

The absence of cointegration is consistent with the results in the relevant literature (see, for example, Pereira, 2000; and Pereira & Andraz, 2003) for the US case, Pereira and Roca (1999) for the Spanish case, and Pereira and Andraz (2005) and Pereira and Andraz (2006) for the Portuguese case]. Furthermore, the lack of evidence for long-term equilibrium relationships is not surprising for an economy that has a long way to go in its process of converging to the level of its EU peers.

3.3 The VAR Specification (Note 5)

We estimate five VAR models. Each VAR model includes the growth rates of output, employment, and private investment. In addition, it includes the growth rates of a different infrastructure investment variable—one model for aggregate infrastructure investment and one for each of the four different types of infrastructure investment. We use the BIC to determine whether exogenous structural breaks and deterministic components, the constant and trend, should be included in the VAR system.

Our test results suggest that a first order VAR specification with a constant and a trend as well as structural breaks in 1989, 1994, and 2000 is the preferred choice for the models with aggregate infrastructure investment, other transportation, social infrastructure, and utilities. The case of road infrastructure requires a second order VAR with the same deterministic components and structural breaks. The identification of structural breaks is very meaningful, as it shows the relevance of the inception of the first three community support frameworks, but the lesser importance of the most recent one, the QREN.

3.4 Identifying Exogenous Innovations in Infrastructure Investment

The central issue in determining the effects of infrastructure investment is the identification of exogenous shocks to infrastructure investment, shocks that are not contemporaneously correlated with shocks in the other variables. In dealing with this issue, we draw from the approach typically followed in the literature on the effects of monetary policy (see, for example, Christiano, Eichenbaum, & Evans, 1996, 1999; and Rudebusch, 1998), and adopted by Pereira (2000) in the context of the analysis of the effects of infrastructure investment. The idea is to imagine a policy function which relates the rate of growth of infrastructure investment to the relevant information set. The residuals from this policy functions are uncorrelated with innovations in other variables.

We assume that the relevant information set for the policy function includes past but not current values of the economic variables. This is equivalent in the context of the standard Choleski decomposition to assuming that innovations in infrastructure investment lead innovations in economic variables. We have two reasons for this assumption. First, it seems reasonable to believe that the economy reacts within a year to innovations in infrastructure investment decisions. Second, it also seems reasonable to assume that the public sector is unable, due to the time lags in information gathering and in public decision making, to adjust infrastructure investment decisions to innovations in the economic variables within a year.

Table 3. Policy Functions for Infrastructure Investments

	gdp_{-1}	emp_{-1}	$gfcf_{-1}$	$Pinv_{-1}$	1989	1994	2000	Const	Trend
Infrastructure	1.48	1.26	0.00	-0.21	-0.10	-0.17	-0.34	-0.08	0.01
	(2.49)	(2.16)	(0.72)	(0.27)	(0.10)	(0.15)	(0.22)	(0.11)	(0.01)
Road Transp.	0.31	-0.11	0.73	-0.12	0.22	0.25	0.50	0.19	-0.02
	(3.48)	(3.00)	(0.94)	(0.20)	(0.15)	(0.20)	(0.30)	(0.15)	(0.01)
Other Transp.	0.04	-2.68	0.78	0.02	0.04	0.03	-0.12	0.03	0.04
	(4.17)	(3.68)	(1.12)	(0.24)	(0.18)	(0.24)	(0.39)	(0.18)	(0.01)
Social	1.97	0.14	0.59	-0.15	-0.04	-0.08	-0.19	-0.04	0.62
	(2.61)	(2.24)	(0.77)	(0.22)	(0.11)	(0.14)	(0.22)	(0.11)	(0.01)
Utilities	2.54	5.47	-1.69	-0.17	-0.41	-0.55	-1.10	-0.29	0.04
	(5.00)	(4.32)	(1.35)	(0.19)	(0.21)	(0.30)	(0.44)	(0.22)	(0.02)

Note. Standard errors in parentheses. * $p<0.05$, ** $p<0.01$.

The different policy functions are presented in Table 3. For aggregate infrastructure investment, as well as for each of the four individual infrastructure types, the policy functions suggest that there is no feedback from the other variables to the infrastructure investment variable. This also means that these variables do not Granger-cause infrastructure investment, and infrastructure investment is truly an exogenous variable. The exogeneity of infrastructure investment decisions in Portugal is easily explained by the fact that, for most of the sample period, infrastructure investment decisions have been closely related to EU structural and cohesion policies.

3.5 The Impulse Response Functions

We consider the effects of one-percentage point, one-time random shocks in the rates of growth of the different types of infrastructure investment on output, employment, and private investment. We expect these temporary shocks in the growth rates of the different types of infrastructure investment to have temporary effects on the growth rates of the other variables. They will, however, also have permanent effects on the levels of these variables.

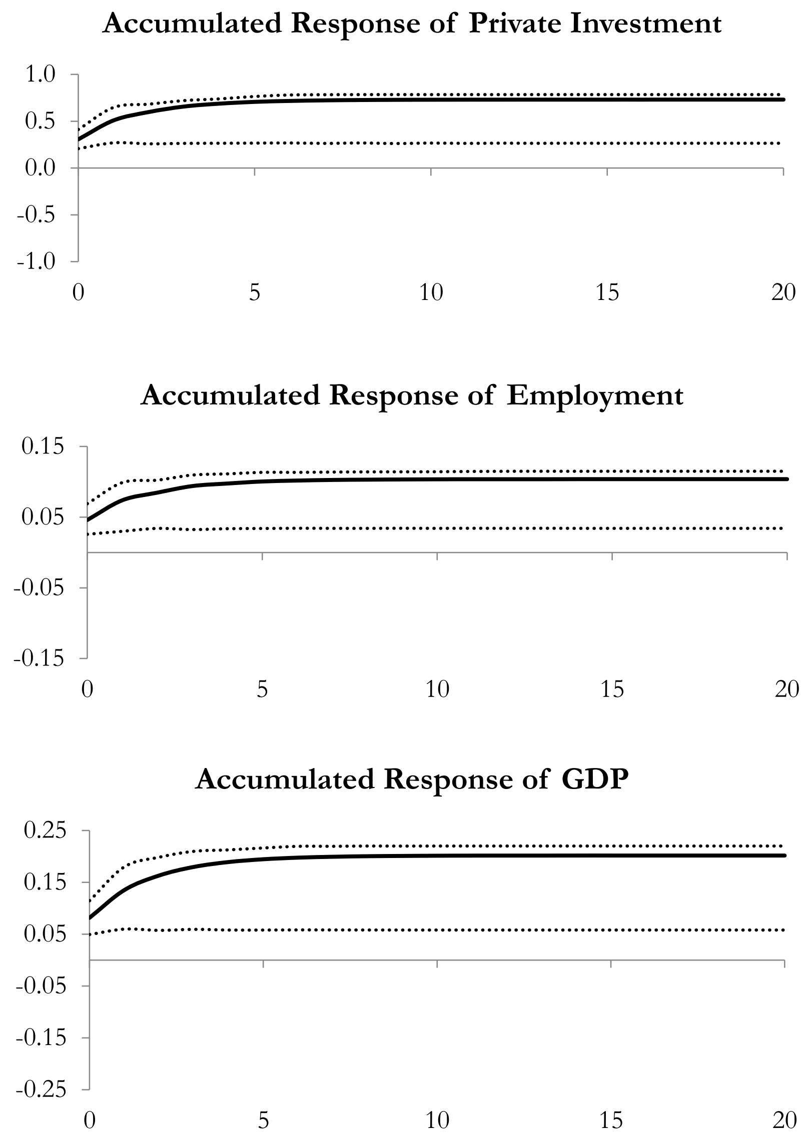

Figure 1. Accumulated IRFs with Respect to Infrastructure Investments

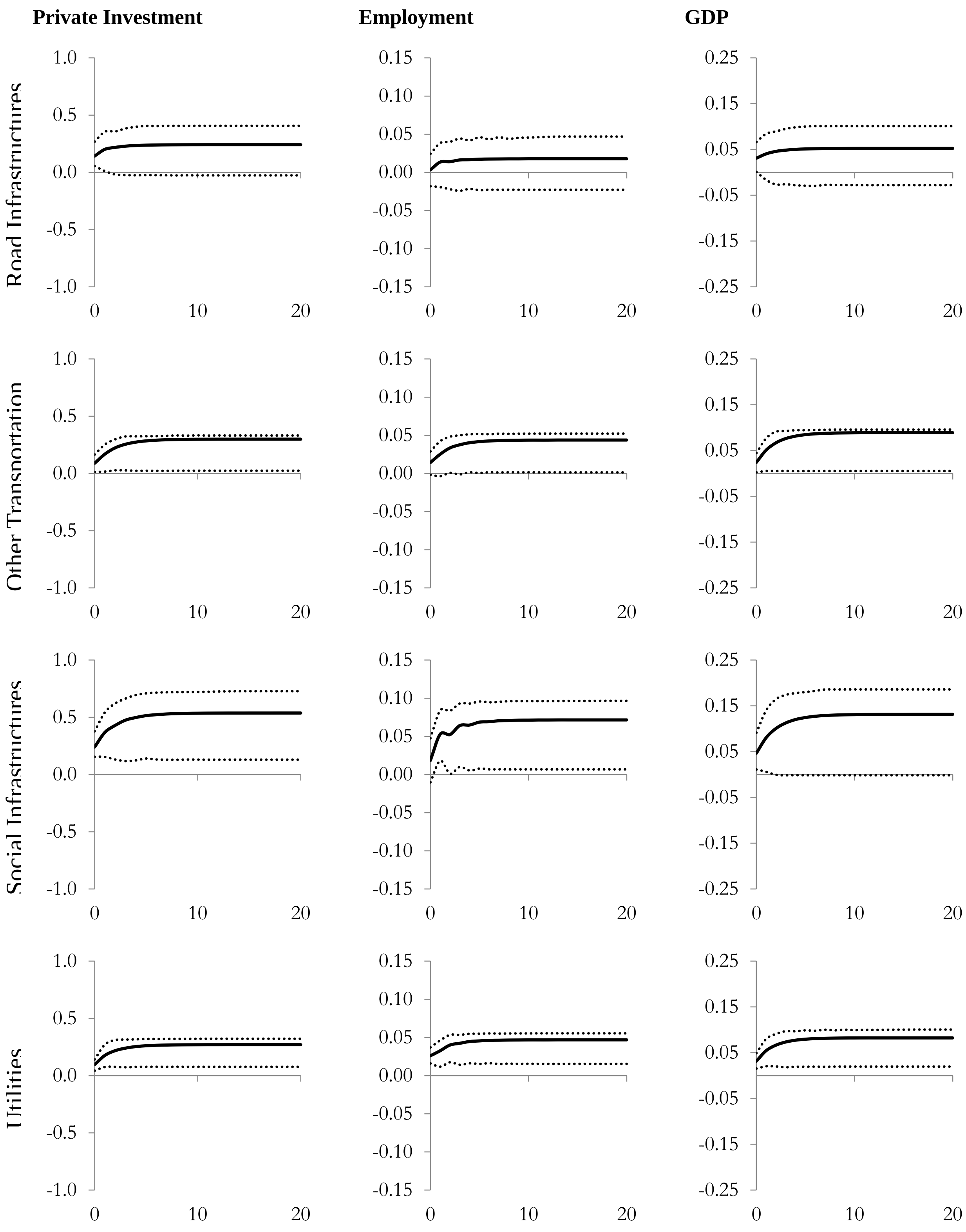

Figure 2. Accumulated IRFs with Respect to Infrastructure Investments by Type

All of these effects are captured through the impulse response functions and accumulated impulse response functions associated with the estimated VAR models. In all cases, standard deviation bands computed via bootstrapping methods were calculated to ascertain the statistical significance of the results. We consider 90% confidence intervals, although bands that correspond to a 68% posterior probability are the standard in the literature (Sims & Zha, 1999). From a practical standpoint, when the 90% error bands for the accumulated impulse response functions include zero in a way that is not marginal (to allow for the difference between the 90% and 68% posterior probability) we consider that the effects are not significantly different from zero.

The accumulated impulse response functions are presented in Figure 1 and in Figure 2. All of them show a smooth convergence pattern within a ten-year period. Furthermore, the estimated standard deviation bands always fall in the positive range of results suggesting that the effects we identify are significantly different from zero. The only exception is the case of the effects on employment and output from road infrastructure in which case the standard deviation bands overlap with the negative range.

4. On the Effects of Infrastructure Investment

4.1 Elasticities with Respect to Infrastructure Investments

The elasticities of output, employment and private investment with respect to infrastructure investment are reported in Table 4 and are obtained from the accumulated impulse response functions. These elasticities measure the total accumulated percentage-point long-term change in the economic variables induced by a one-percentage point accumulated long-term change in infrastructure investment.

The results at the aggregate level suggest that investment in infrastructure crowds in both private investment and employment. Indeed, we estimate that the elasticity of private investment with respect to aggregate infrastructure investment is 0.6205, and the elasticity of employment with respect to aggregate infrastructure investment is 0.0881. Given the positive effects on private investment and on employment, we find a positive impact on output. Indeed, our results suggest that aggregate infrastructure investment has a positive effect on output, with an elasticity of 0.1712.

At a more disaggregated level, considering the elasticities with respect to the four types of infrastructure, we observe that they are all positive and within relatively-narrow ranges. The elasticities of private investment range from 0.2292 for road transportation to 0.3911 for social infrastructure; the elasticities of employment range from 0.0169 for road transportation to 0.0547 for public utilities; and the elasticities of output from 0.0496 for road transportation to 0.0962 for public utilities. It should be noted that, in general, the elasticities are lower for road transportation and other transportation than for social infrastructures and public utilities on the other, reflecting a stronger structural connection to the rest of the economy on the part of the latter. It should be noted that with one exception, the results above are all statistically different from zero, and strongly so, as suggested by the standard deviation bands around the accumulated impulse response functions. The exception is road infrastructures, in which case the results for employment and output are not statistically different from zero with our more stringent confidence bands but would be significant with more conventional levels and less-stringent confidence intervals.

Table 4. Elasticities with Respect to Infrastructure Investments

	Private Investment	Employment	Output
Infrastructure Investments	0.6205	0.0881	0.1712
	[0.0249,0.6205]	[0.0035,0.0881]	[-0.0150,0.1712]
Road Transportation Infrastructure	0.2292	0.0169	0.0496
	[-0.0803,0.2292]	[-0.0238,0.0169]	[-0.0381,0.0496]
Other Transportation Infrastructure	0.2596	0.0379	0.0772
	[0.0881,0.2596]	[0.0130,0.0379]	[0.0275,0.0772]
Social Infrastructures	0.3911	0.0521	0.0956
	[0.0117,0.3911]	[0.0127,0.0521]	[-0.0189,0.0956]
Utilities	0.3156	0.0547	0.0962
	[0.020,0.3156]	[0.0024,0.0547]	[0.0006,0.0962]

Note. In parentheses we present the range of variation under the different Choleski orthogonalization strategies. These ranges do not represent and should not be understood as confidence intervals. They consider the range of variation for all statistically possible strategies, which we ruled out on economic grounds.

4.2 Effects of Infrastructure Investments on Labor Productivity

The effects of infrastructure investment on labor productivity can be determined from the relative magnitudes of the output and employment elasticities with respect to infrastructure investment. To the extent that changes in infrastructure investment have a larger effect on output than on employment, this implies that these investment activities increase output per worker and therefore the productivity of the workforce. The effects of infrastructure investments on labor productivity are depicted in Figure 3.

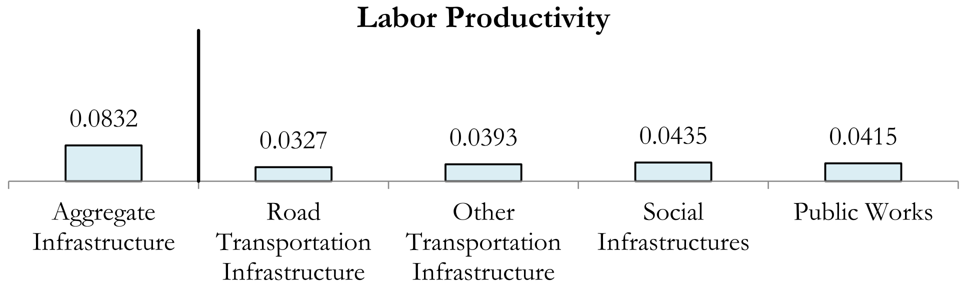

Figure 3. Effects of Infrastructure Investments on Labor Productivity

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The elasticity of output with respect to aggregate infrastructure investment is significantly larger than the elasticity of labor, which implies that investment in infrastructures has led to a significant increase in labor productivity in Portugal. At a more disaggregated level we see important, albeit more tenuous, effects. Investments in social infrastructures and public utilities have the largest effects on labor productivity, 0.0435 and 0.0415, respectively. In turn, road transportation and other transportation have lower but still very significant effects, 0.0327 and 0.0393, respectively.

4.3 Marginal Products with Respect to Infrastructure Investment

The marginal products of infrastructure investment measure the long-term accumulated Euro change in private investment and output, and the number of permanent jobs created, for each additional Euro of investment in infrastructures. The marginal product figures are obtained by multiplying the average ratio of each variable to infrastructure investment by the corresponding elasticity. We use average ratios for the last ten years of the sample. This allows the marginal product to reflect the relative scarcity of the different types of infrastructures at the margin of the sample period without being overly affected by business cycle factors. Accordingly, the marginal product figures are the most interesting from a policy perspective as they capture the effects of scarcity in addition to the effects of the coupling of infrastructure investment and the economy as reflected in the elasticities. The marginal products are presented in Table 5.

Table 5. Marginal Products of Infrastructure Investments

	Private Investment	**Employment**	**Output**
Infrastructure Investments	2.5115	0.0523	2.7692
	[0.1007,2.5115]	[0.0021,0.0523]	[-0.2419,2.7692]
Road Transportation Infrastructure	3.1801	0.0343	2.7492
	[-1.1145,3.1801]	[-0.0484,0.0343]	[-2.1138,2.7492]
Other Transportation Infrastructure	12.6197	0.2706	14.9993
	[4.2817,12.6197]	[0.0925,0.2706]	[5.3426,14.9993]
Social Infrastructures	8.6569	0.1692	8.4546
	[0.2594,8.6569]	[0.0413,0.1692]	[-1.6690,8.4546]
Utilities	2.8891	0.0735	3.5198
	[0.1828,2.8891]	[0.0033,0.0735]	[0.0212,3.5198]

Note. In parentheses we present the range of variation under the different Choleski orthogonalization strategies. These ranges do not represent and should not be understood as confidence intervals. They consider the range of variation for all statistically possible strategies, which we ruled out on economic grounds.

For total infrastructure at the aggregate level we find a marginal product of private investment of €2.51. This means that, at the aggregate level, infrastructure investment crowds in private investment, and that one Euro of additional infrastructure investment will induce, in the long term, an accumulated total of €2.51 of private investment. In turn, our results suggest that at the aggregate level, 52.3 additional permanent jobs are created in the long term for each additional one million Euros in infrastructure investment.

In terms of output, we estimate an aggregated marginal product of €2.77. This implies that the increase of one Euro in infrastructure investment leads to a total accumulated increase of €2.77 in output over the long term. This marginal product implies a rate of return of 3.45%, assuming that the infrastructure assets have an average lifespan of thirty years.

Naturally, the more aggregate results are just indicative. Let's now consider the magnitude of the effects at a more disaggregated level, so as to identify more nuanced patterns. Here we see that the largest positive effects of infrastructure investment on private investment come from other transportation and social infrastructure, €12.62 and €8.66, while the largest effects on employment come from other transportation, with 271 long-term jobs per million Euros, and from social infrastructure with 169 permanent jobs per million Euros.

The same pattern can be observed in terms of the impact of the different types of infrastructure on output. The largest effects come from investment in other transportation infrastructures, with a marginal product of €15.00 and social infrastructure with a marginal product of €8.45. These values imply annualized rates of return over thirty years of 9.45% and 7.37%, for other transportation and social infrastructures, respectively, rates which are very competitive by market standards. The multipliers for road transportation and of public utilities are significantly smaller, €2.75 and €3.52, respectively, with rates of return that are also significantly smaller, 3.43% and 4.28%, respectively.

4.4 On the Potential Long-Term Budgetary Effects of Infrastructure Investment

To identify the potential budgetary effects of investments in a given infrastructure we consider the marginal product of output with respect to that variable. The potential budgetary effect of an investment depends on the amount of additional tax revenue generated by enhanced output conditions that are induced by the investment.

We can consider the issue of whether or not an investment pays for itself in the form of additional tax revenues in different ways. We can consider the effective tax rate in the economy and apply it to the marginal product to generate the additional tax revenues. If the amount of additional tax revenue exceeds 1 Euro then the investment pays for itself. Alternatively, one could calculate the break-even effective-tax rate necessary for an investment to pay for itself given the marginal returns to its investment. If the break-even tax rate is below the tax rate observed in the economy, then the investment does not pay for itself. Still, another way is to consider the payback period, that is, for given a fixed effective tax rate how many years would it take for the investment to pay for itself. If this time horizon is less than the life expectancy of the asset then the investment pays for itself. The potential long-term budgetary effects of infrastructure investments are presented in Table 6.

At the aggregate level, our results suggest that one Euro in aggregate infrastructure investment would pay for itself in the long term in the form of increased tax revenues only for an effective tax rate in the economy in excess of 36.1%.

The more disaggregate effects are very informative. All marginal products are positive so that in our taxonomy all infrastructure investment types fall clearly in either case two or case three, i.e., they induce relevant economic effects. The only question is what to expect in terms of budgetary effects. Here there is a significant difference. Investments in other transportation and in social infrastructures would be self-financing even for very low effective tax rates. Investments in road transportation and in public utilities, however, would only come close to paying for themselves under effective tax rates in excess of 36.4% and 28.4%, respectively.

Table 6. Long-Term Budgetary Effects of Infrastructure Investments

	Break-even tax rate	**Revenues with tax rate of 25%**	**Years to pay for itself with a tax rate of 25%**
Infrastructure Investments	36.1%	€0.69	44
Road Transportation	36.4%	€0.68	44
Other Transportation	6.7%	€3.75	8
Social Infrastructures	11.8%	€2.11	14
Utilities	28.4%	€0.88	36

An alternative, but informative, way of looking at these figures is to consider that under a linear distribution of the long-term effects over a lifetime of thirty years, and assuming for the sake of illustration, an effective tax rate on the additional output of 25%, investments in other transportation infrastructures and social infrastructures would take eight and fourteen years to pay for themselves, respectively. In turn, investments in road transportation infrastructures and in public utilities would take forty four and thirty three years, respectively, and therefore a time frame much longer than the standard expected lifetime of this type of assets.

4.5 Long-Term Marginal Products versus Effects on Impact

Infrastructure investments can be expected to have two types of effects. First, there are short-term demand-side effects that are induced by the very implementation of the investment efforts, mainly the construction of the infrastructure and how it reverberates throughout the economy. Second, there are longer-term supply side-effects that reflect the impact of the availability of the infrastructure on economic performance. In Table 7 we report the decomposition of the marginal products of infrastructure investment in a way that, in addition to the total accumulated long-term effect, shows how much of this total effect is due to a demand side-effect on impact. The difference between the two is, naturally, the longer-term supply side-effect.

For total infrastructure investment, we estimate effects on impact of 42%, 44% and 49% of the total effect for private investment, employment, and output, respectively. This means that a very sizable part of the economic as well as budgetary effects would occur almost immediately.

Table 7. Marginal Products versus Effects on Impact

		Private Investment	**Employment**	**Output**	**Short Term Average %**
Infrastructure Investment	Total	2.51	0.05	2.77	
	Short Term	1.05	0.02	1.12	
	(%)	(42%)	(44%)	(40%)	(42%)
Road Transportation	Total	3.18	0.03	2.75	
	Short Term	1.88	0.01	1.63	
	(%)	(59%)	(19%)	(59%)	(46%)
Other Transportation	Total	12.62	0.27	15.00	
	Short Term	3.75	0.09	4.07	
	(%)	(30%)	(33%)	(27%)	(30%)
Social Infrastructures	Total	8.66	0.17	8.45	
	Short Term	3.87	0.04	3.00	
	(%)	(45%)	(26%)	(35%)	(35%)
Utilities	Total	2.89	0.07	3.52	
	Short Term	1.03	0.04	1.35	
	(%)	(36%)	(55%)	(38%)	(43%)

When we consider the four main types of infrastructure investment, we obtain a clearer picture. In terms of road transportation, the bulk of the effects on private investment and output, 59% specifically, are short-terms effects on impact. This suggests that the declining pattern of small and decreasing effects have pretty much eroded the long-term supply side benefits of these infrastructures and most of what is left is short-term demand side effects related to construction. An exception to this pattern is the employment effects. The short-term employment effects are a very small part—just 19%—of what is, in any case, a very small accumulated long-term effect.

For other transportation, the short-term effects on impact are 30%, 33%, and 27% of the total accumulated long-term effects for investment, employment, and output. This means that aside from the short-term demand-side effects related to construction, there are also quite sizable long-term supply-side effects to the economy. It could be noted that in terms of their magnitude, the short-term effects on impact of other infrastructure are larger than the overall long-terms effects of either road transportation or utilities.

In the case of social infrastructures, the other area of significant economic and budgetary potential, the short-term effects on impact are also moderate, about 45% for private investment, 26% for employment and 35% for output. This means that the long-term supply-side effects also dominate as in the case of other transportation. Equally interesting is that all of the short-term effects of social infrastructure investments are comparable or larger than the total effects of both road infrastructure and utilities.

Finally, for public utilities, we find that the short-term effects on impact are across the board stronger than those for other transportation, stronger than the short-term impact effects of social infrastructure on employment and output, and stronger than the short-term impact effects of road transportation on employment.

4.6 Long-Term Marginal Products and the Relative Scarcity of Infrastructures

Economic theory suggests that a pattern of diminishing marginal returns to infrastructure capital should be expected, meaning that, with a more developed stock of infrastructure, incremental investment flow should have progressively smaller economic effects. In this context, it is important to recall that the marginal products with respect to infrastructure investment presented in this work are computed using infrastructure investment and the other relevant economic data for the last ten years. This recent period is chosen to reflect the most recently available data and accurately reflect the effect of infrastructure scarcity on the economic impact of infrastructure investment at the margin. A ten year period is chosen to ensure that the results are not overly affected by business cycle fluctuations.

To assess the evolution of the effects of scarcity on the measurement of the marginal products with respect to infrastructure investment throughout the sample period, next we present the marginal products using alternative time periods. Specifically, we consider 10-year moving averages beginning in 1978, thereby tracing the evolution of the marginal products as reflecting the evolution of the relative scarcity of the infrastructure asset. This information is particularly useful in depicting the specific patterns of diminishing marginal productivity of infrastructure investment in the different cases and specifically how fast it is decreasing. This is fundamental in evaluating the potential for policies to encourage the development of additional infrastructures.

The evolution of the marginal products for total infrastructure investment and the four main types of infrastructure assets are presented in Figure and Figure 5, respectively. As a point of reference, the values for the marginal products we have presented in Table 5 and discussed above, are the very last points in the different figures, that is, are the points where each curve ends using averages for the last ten years of the sample.

At the aggregate level, a pattern of diminishing marginal returns is clear in all cases. In terms of the effects on private investment, with current values for the marginal products of investment, employment and output now at about 60%, 37%, and 55%, respectively, of the values implied by the scarcity earlier in the sample, specifically, by the end of the 1990s.

Considering the four main types of infrastructure assets provides a very rich differentiation amongst the evolution of the marginal products of the different infrastructure investment. Indeed, for road transportation, we see a pattern of steady decline of marginal products, one that is more pronounced earlier in the sample period than over the last ten years. Indeed, the marginal products at the end of the sample are just 50%, 34%, and 47%, for investment, employment, and output, of the values observed by the end of the 1990s. This is consistent, naturally, with a pronounced effort throughout the sample in the development of road transportation infrastructures and the concomitant reduction of the relative scarcity of these infrastructures. Indeed, the investment efforts in road transportation as a percentage of GDP increased consistently throughout the three decades of our sample period. The case of public utilities is similar both qualitatively and quantitatively to the case of road transportation we just described.

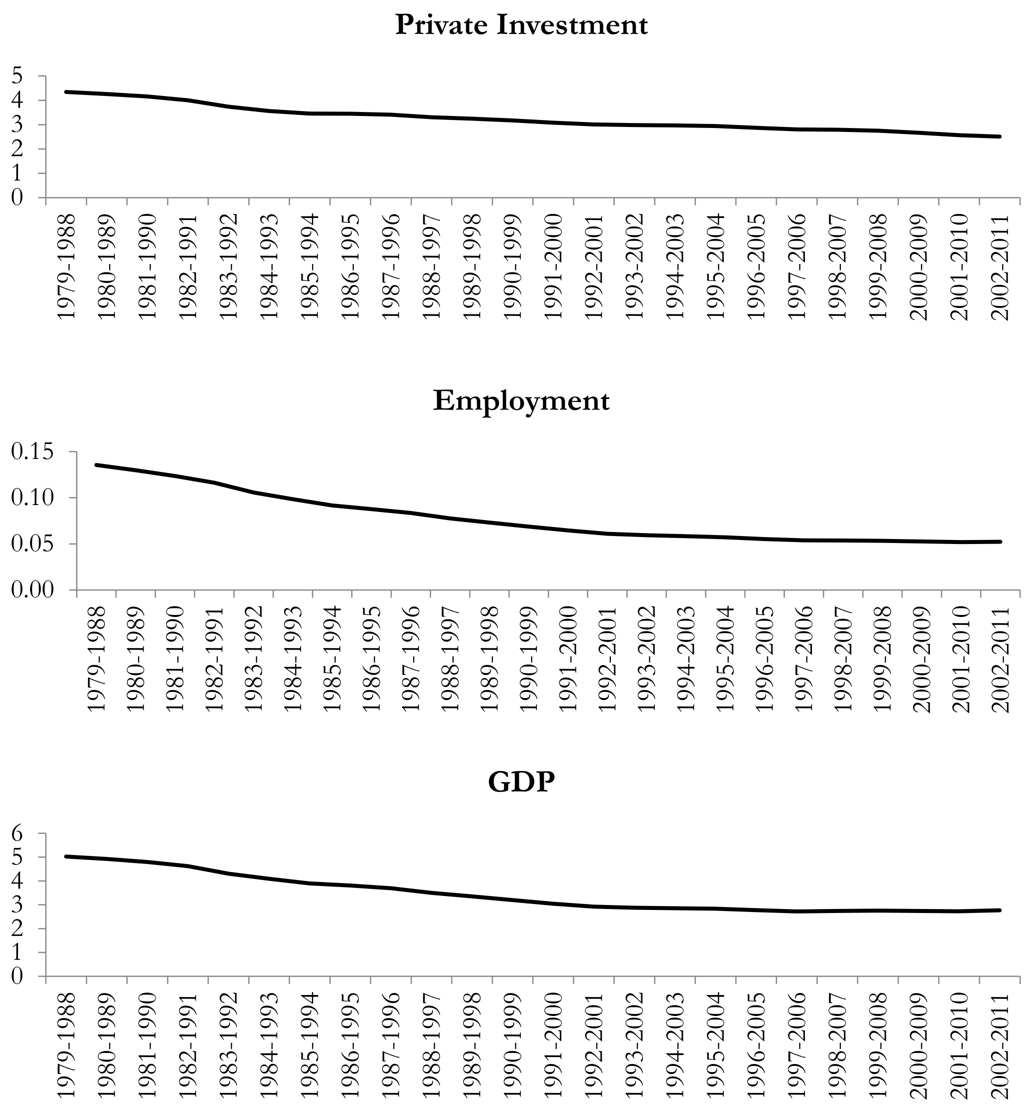

Figure 4. Marginal Products Using Alternative Sample Periods

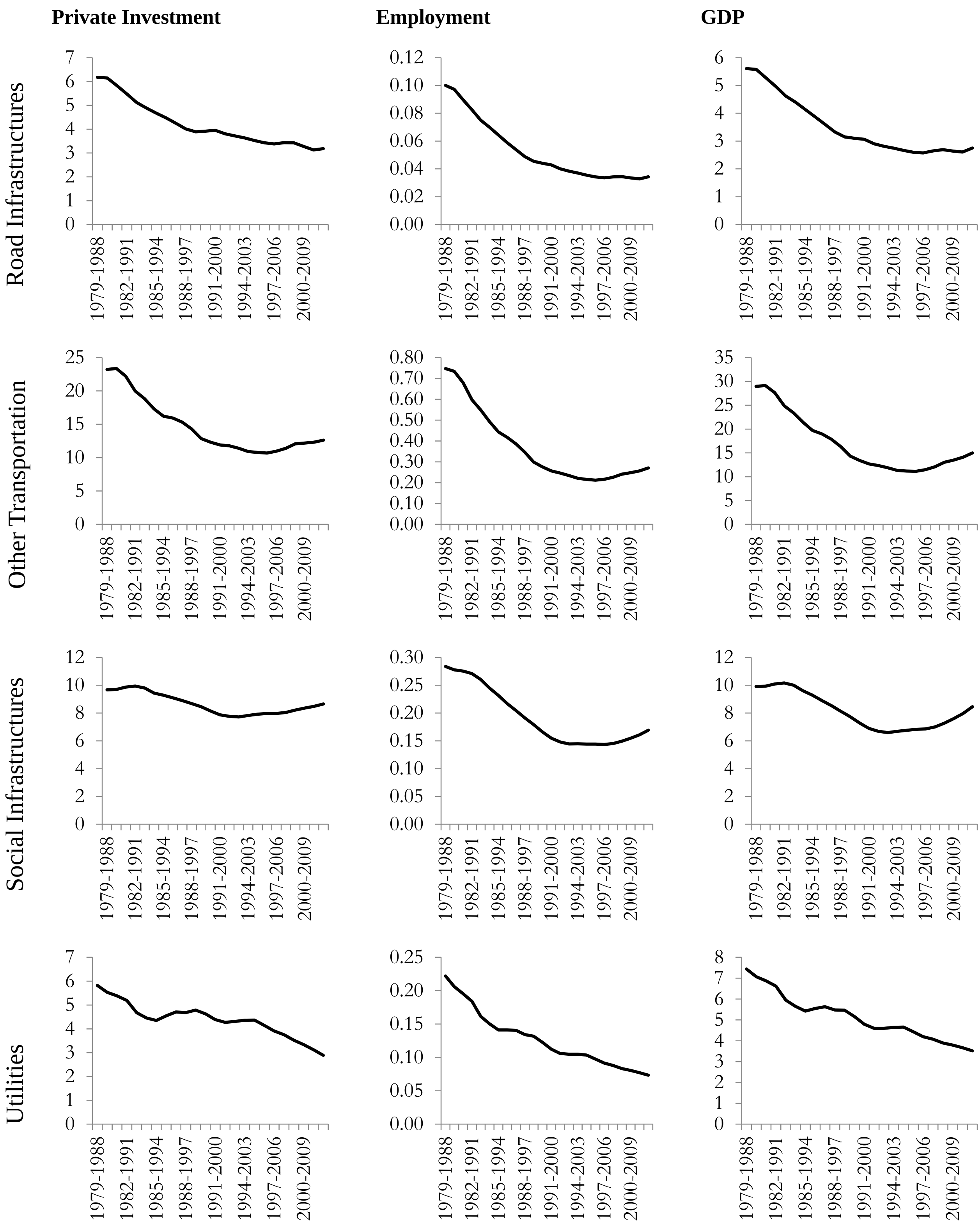

Figure 5. Marginal Products Using Alternative Sample Periods by Type

For other transportation infrastructures as well as for social infrastructures we also see an overall pattern of decreasing marginal returns, although less pronounced and indeed with a small inflection point after the early 2000s. The levels of marginal productivity measured at the end of the sample period are actually remarkably close to the levels as measure at the end of the 1990s. This is consistent with the idea that investments in these infrastructures, while having received some attention in the latter part of the sample, did not play center stage in the investment strategies throughout the sample period. Indeed, with a total as a fraction of GDP that stagnated, the shares of these investments in total infrastructure investment declined from the 1990s to the 2000s.

5. International Comparisons

Making meaningful international comparisons is surprisingly difficult. This is because of wide differences in the temporal and typological scope and definition of the data sets, the differences in econometric approaches, as well as the interpretation of the figures they yield. Because of this we focus here on comparisons with the evidence on the output effects of infrastructure investment in Ontario, Canada (see Pereira, A. & Pereira, R., 2014), U.S. (see Pereira, 2000), Spain (Pereira & Roca, 2003, 2007), and Portugal (see, Pereira & Andraz, 2005, 2011). Canada and the U.S. provide for a comparison with economies at a greater level of development and with arguably a lower level of infrastructure scarcity. In contrast, Spain provides for a comparison at a similar level of development and scarcity in the infrastructure stock. Naturally, the most interesting comparisons will be with previous evidence for Portugal itself. These comparisons are presented in Table 8.

Table 8. International Comparisons for the Marginal Products of Infrastructure Investments

	Present Study	**Portugal**	**Spain**	**United States**	**Ontario, Canada**
	1980-2011	1978-98	1970-95	1956-97	1976-2011
Transportation Infrastructures			5.50		
Road Transportation Infrastructures	2.75	18.06		1.97	
Other Transportation Infrastructures	15.00	19.00		19.79	29.19
Non-Transportation Infrastructures					
Social Infrastructures	8.45			5.53	
Education					14.17
Health					23.46
Public Utilities	3.52				
Water Infrastructures				6.35	8.29

The estimate for the output effects of road transportation investments for the US is 1.97, the smallest effect among the infrastructure types considered, while for Ontario the multiplier for road infrastructures is actually negative. Our estimate of 2.75 although larger than these two cases is similarly, the smallest among the infrastructure types considered. In terms of the multipliers for other transportation infrastructure investments, the closest category for the U.S. study is core infrastructure which includes transit and airfields—but also electricity and gas. The estimated multiplier for core infrastructures in the U.S. is 19.79 and is the largest among the infrastructure types considered. For Ontario, the largest multiplier is also for transit with a marginal product of 29.19. Our estimate for Portugal including airports, ports and railroad infrastructure is similarly the largest at 15.00.

The evidence for Spain considering total transportation infrastructure—road and other transportation—suggests a multiplier of 5.50. This figure can be compared to the evidence for Portugal for a comparable time horizon for investments in roads and other transportation infrastructures, multipliers of 18.06 and 19.00, respectively. The natural conclusion is that the marginal benefits of further investments transportation infrastructure were greater at the time for Portugal than Spain, reflecting a pattern of greater relative scarcity in Portugal.

In turn, for the U.S. the multiplier for the infrastructure type that most resembles social infrastructure—but also includes administrative buildings—is 5.53, and is in the middle of the range of results, while for Ontario the estimate of the multiplier for education infrastructure is 14.17 and health infrastructure is 23.46 and are among the largest. Our estimate for social infrastructure is 8.45 and is only second to other transportation infrastructure. Finally, for utilities, the estimates for the U.S. for water and water systems are 6.35 while for Ontario the same multiplier is 8.29. Our multiplier for utilities is 3.52 but comparing it to these figures has to be very tentative as we also include in this category, electricity and gas, refineries, and telecommunications.

Let us now consider the comparisons with previous estimates of the multipliers for Portugal. Our current results for road transportation and for other transportation are to be contrasted with multipliers for the period ending in the late 1990s of 18.06 for road infrastructures, and around 19.0 for other transportation. The multiplier for road transportation is now 6.5 times smaller. This reflects a rapid decline in the marginal productivity of these investments and the decoupling of road infrastructure investments and economic performance. In turn, for other transportation the values are somewhat smaller but certainly not to the same degree.

6. Summary and Policy Implications

The goal of this paper is to identify priorities in infrastructure investments in Portugal, i.e., areas of infrastructures investments with virtuous economic and budgetary effects. Our main conclusions and Policy implications can be summarized as follows.

First, we find that investments in other transportation and social infrastructures have important economic effects while investments in road infrastructures or public utilities less so. Furthermore, reducing investments in road infrastructures and in public utilities may help the public budget, but cuts in other transportation investments and in social infrastructure investments will not. They will, in fact, likely have a detrimental effect on the public budget.

Second, and equally important, the positive effects on the economy and the budget from investments in other transportation infrastructures and social infrastructures although they continue in the longer term are already very significant in very short term—the point is that the authorities do not have to wait long for the positive effects to be evident. Our results suggest that the types of infrastructure investment with the largest accumulated effects—other transportation and social infrastructures—are also the ones where the short-term effects are in relative terms on average the least important. In absolute terms, however, we see that other transportation and social infrastructure dominate also in terms of the magnitude of the short-term effects. This means that even if the objective of infrastructure investment were simply to be employed as a demand-side tool to promote employment and economic activity, investments in other transportation and social infrastructures would still be the best bets for the public sector. Furthermore, and from a budgetary perspective, these investments would pay for themselves on impact even with relatively low effective tax rates.

Third, the patterns of evolution of the marginal products are very interesting from a policy perspective. The marginal products for road infrastructure and public utilities currently tend to be small, and show a strong declining pattern throughout the sample. The expectation therefore should be that future investments in these areas would generate small and progressively-declining effects. Their economic effect is becoming smaller and their budgetary effects moving more and more into the potentially detrimental region. Therefore, we reinforce the idea presented above that these do not seem to be key areas for public policy efforts. In turn, the opposite is true for investments in other transportation and social infrastructure. These show large and relatively stable marginal products over the last decade adding to their desirability both in economic and budgetary terms.

These results have clear policy implications and help substantiate the terms of the current debate on the future of infrastructure investments in Portugal. Our recommendation for a strategic focus on other transportation infrastructure is consistent with the concern that investments in railroads and ports have been neglected and the investments in railroads have been rather insufficient. Our results give substance to the recommendations of a government-appointed group to heuristically identify priorities in transportation infrastructure investment (see Ministério da Economia, 2014). Their recommendation focused mostly on railroad and port investments.

In turn, our recommendation for a strategic focus on social infrastructures needs some elaboration. First and foremost, it needs to be clear that we are not considering current spending in education and health, in general, but rather investments on health and education structures. As such the effects identified do not reflect directly improved delivery of social services but rather an improved and increased availability of such structures, which will eventually facilitate improved service delivery. This said, it is important to highlight that social infrastructure investments are those among the specified investment categories that have had the greatest impacts on employment. In part, this is due to the nature of the construction efforts as well as the need of additional employment to populate the new structures. One would, however, eventually expect the additional structures to induce over the long-term improved educational and health outcomes, which would translate into an improved quality of the labor force. In fact, we estimate social infrastructures have one of the lowest shares of the short term effects on employment total effects as well as the largest effects on labor productivity come from investments in social infrastructures.

Finally, our recommendation to move away from road infrastructure investment fits into and substantiates the common wisdom that this is an exhausted strategy. It is also consistent with the view of the European Commission in their refusal to allocate any further community funds in the context of the structural policy and cohesion programs to these types of projects. Our recommendation to move away from investments in utilities is also consistent with the fact that a lot of the sector has been privatized and therefore these investments are progressively out of the jurisdiction of the public sector and will be undertaken only to the extent that private profitability is guaranteed.

Because of their immediate relevance for policy making it is prudent to conclude with a cautionary note. Our results establish the relevance of infrastructure investments both in absolute and in relative terms. They cannot be regarded as implying that infrastructure investments are the only factor or even the most important behind any economic change we have observed in the economic fabric of the country. Clearly, we do not contrast the effects of infrastructure investments with any other major drivers of the economic growth in the country over the last several decades, such as, joining the EU, increased openness to foreign trade, market liberalization, foreign direct investment, financial integration, or the adoption of the Euro just to name a few (Note 6). They cannot either be regarded as implying that infrastructure investments are the most effective tools in achieving economic growth while strengthening budgetary consolidation. Clearly, we do not compare the effects of infrastructure investments with the effects of other public policies, namely fiscal policies, tax reductions, other expenditure programs, or investment subsidies.

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Notes

Note 1. This work is also related to the voluminous literature on fiscal multipliers, i.e., on the macroeconomic effects of taxes and government purchases (see, for example, Baunsgaard et al., 2014; and Ramey, 2011; for recent surveys of this literature, and Leduc and Wilson (2012) for a related analysis). It is in fact very much in the spirit of the approach pioneered by Blanchard and Perotti (2002), which is based on a VAR approach and uses the Choleski decomposition to identify government spending shocks. We focus, however, on a specific type of public spending—infrastructure investment and the channels through which it affects the economy, as opposed to aggregate spending as it is traditional in this literature. In this sense, this paper is closer in focus to Leduc and Wilson (2012).

Note 2. This new data set was the result of a research project developed under the auspices of the Fundação Francisco Manuel dos Santos. The main purpose of this project was to develop a comprehensive data set on infrastructure investments in Portugal that could be made available to academic researchers and policy makers alike. This data set was made public in March of 2016 and, in the interim, the Portuguese Ministry of the Economy has acquired the rights to this data set and is currently in the process of setting up the procedures for its maintenance and update as part of the official public data.

Note 3. Detailed test results are available from the authors upon request.

Note 4. We have chosen this procedure over the often used Johansen approach, since we do not have any priors that suggest the possible existence of more than one cointegrating relationship, the Johansen approach is not strictly necessary. More importantly, however, for smaller samples based on annual data, Johansen's tests are known to induce a strong bias in favor of finding cointegration when it does not exist (although, arguably, the Engle Granger approach suffers from the opposite problem).

Note 5. Again, detailed results are available from the authors upon request.

Note 6. In this context it is relevant to mention that the only relevant time dummies identified by our structural break analysis coincided with the different structural programs. Specifically, a time dummy for 1986, the date of Portugal joining the EU was not significant. On the other hand, it can also be conjectured that the significance of the time dummy in 2000 reflects not just the differences in the structural programs before and after but the fact that the period after coincides with the adoption of the Euro. Interestingly enough, the period after 2000s was a period of great deceleration of infrastructure investment and of rather low GDP growth. This means that the potential benefits from the common currency may have masked the effects lower infrastructure investment thereby leading to a downward bias in our estimates of the effects of infrastructure investment.

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